

A Precursor Material for the Production of Mechanical Objects and a Method of Production

Cross-reference to Related Application

5 **[0001]** This application claims priority to Chinese Patent Application No. 03 101 978.1, filed January 30, 2003, the entire disclosure of which is incorporated herein by reference in its entirety as if fully set forth herein.

Background of the Invention

10 Field of the invention

[0002] The present invention relates to the production of a precursor material suitable for the production of mechanical objects by a forming process.

15 Description of the Related Art

[0003] In daily living, society uses significant amounts of disposable containers, frequently made from plastics or Styrofoam®, or eco-plastics. Despite the convenience of these materials, the poor biodegradable characteristics that they exhibit is causing significant damage to the environment. Styrofoam®, for example, is known to take up to 200 years to
20 degrade. Eco-plastics use small grains of plastic bound with starch. This composition hydrolyses with water and leaves behind specks of plastic that

cause soil infertility and are difficult to extract from the soil.

[0004] Chinese Patent No. 1355261 discloses a "Making of biodegradable tablewares, its formula and its process". Chinese patent application No. 02114935.6 discloses "Biodegradable tableware, its manufacturing". Chinese patent application No. 02132545.6 discloses "Starch based environmental material and its making". These patent specifications describe materials where starch is used as the precursor material, making them expensive to produce.

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Brief Summary of the Invention

[0005] According to a first aspect of the present invention, there is provided a method of producing a precursor material suitable for the production of mechanical objects by a forming process, comprising the steps of introducing natural, relatively hard, solid vegetable material consisting substantially of cellulose; combining starch; adding a binding agent to produce a first mixture; drying said first mixture; and milling said dried mixture to produce a precursor powder.

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[0006] According to a second aspect of the present invention, there is provided a first mixture suitable for the production of mechanical objects, consisting of: solid material derived from a vegetable source of a substantially solid consistency; starch; and a binding agent.

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Brief Description of the Several Views of the Drawings

- [0007] *Figure 1* shows an overview of a procedure for producing mechanical objects by a forming process;
- 5 [0008] *Figure 2* shows a step in the procedure overview of *Figure 1* in more detail;
- [0009] *Figure 3* shows an example of a portion of a cellulose chain;
- [0010] *Figure 4* shows a step in the procedure overview of *Figure 1* in more detail;
- 10 [0011] *Figure 5* shows a typical starch molecule;
- [0012] *Figure 6* shows a step in the procedure overview of *Figure 1* in more detail;
- [0013] *Figure 7* shows a typical example of a lipid molecule;
- [0014] *Figure 8* shows procedures for processing precursor material;
- 15 [0015] *Figure 9* shows a procedure for producing mechanical objects;
- [0016] *Figure 10* shows a first mechanical object formed from precursor material;
- [0017] *Figure 11* shows a first mechanical object formed from precursor material;
- 20 [0018] *Figure 12* shows a first mechanical object formed from precursor material.

Written Description of the Best Mode for Carrying Out the Invention

[0019] An overview of a procedure for producing mechanical objects by a forming process is illustrated in *Figure 1*. At step **101** initial components are prepared; essentially raw materials used in the production process. At step **102** a precursor material is produced from the initial components prepared at step **101**, preferably in the form of a powder. Usually, the production of mechanical objects is performed elsewhere and the material is suitable for the production of many different types of object. Thus, at step **103** the precursor material produced at step **102** is stored and may be transported. At step **104** the received precursor material is unpacked and processed so as to produce mechanical objects for use in many different applications.

[0020] Process **101** for the preparation of initial components, as identified in *Figure 1*, includes the preparation of a vegetable material, as illustrated in *Figure 2*, the preparation of a starch material, as illustrated in *Figure 4* and the preparation of a binding agent as illustrated in *Figure 6*. Thus, step **101** may be considered as step **101a**, step **101b**, and step **101c**.

[0021] Step **101a** for the preparation of material matter is illustrated in *Figure 2*. Preferably the material is relatively hard and derived from a vegetable source and therefore consists substantially of cellulose. Organic fibre materials are preferred such as husks, straws, appropriate food waste, starch or sawdust. Typical husks include rice husks, wheat husks, wheat chaff,

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sorghum chaff, peanut shells, coconut shells and other types of nut shell. Similarly, straws may include wheat straws, maize straws and sorghum straws. Suitable food waste materials include bagasse, soy bean residue, wine lees and betel palm waste. Furthermore, suitable starch sources include cornflour, riceflour, potato starch and tapioca.

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[0022] Preferably, this organic fibre material may be recycled from natural agricultural waste fibre. However, care must be taken when recycling waste fibres in that the material may contain contaminants. The inclusion of contaminants may not render the material totally unsuitable but its degree of application may need to be constrained. Thus, it would not be possible to use contaminated material for application for the production of food storage apparatus although material of this type could be used for objects such as ashtrays etc.

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[0023] At step **201** the vegetable material is recovered, preferably as part of a waste recovery process. Thus, a typical foodstock would include husks, as previously detailed, which would previously have been merely discarded. The vegetable material may comprise material from a combination of vegetable sources. Thus, a useful application has been developed for products that would otherwise be merely treated as waste.

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[0024] At step **202** the material is cleaned, clearly to an extent dependent

on its initial source. Thereafter, at step **203**, the material is ground and, in a preferred embodiment, the organic material is preferably ground to a size of particles in the region of **20** micrometers or slightly greater.

5 **[0025]** As previously stated, the vegetable fibre foodstock consists substantially of cellulose. An example of a portion of a cellulose chain is illustrated in *Figure 3*. Cellulose is an example of a polysaccharide in which the monomeric glucose units are arranged with D-glucopyranosides units linked in a 1:4 fashion in very long unbranched chains. The linkages are beta-glycosidic
10 (unlike starch) and the chains are essentially linear. When two or more cellulose chains make contact, the inclusion of hydroxyl groups results in the formation of hydrogen bonds, which in turn holds the chains together resulting in a fibrous insoluble polymer.

15 **[0026]** Procedure **101b** for the preparation of the starch initial component is illustrated in *Figure 4*. At step **401** the agricultural starch source, such as rice or potatoes etc, is harvested. The starch material may comprise material from a combination of starch sources. At step **402** the harvested source is cleaned and at step **403** operations are performed to remove the starch from its
20 agricultural source. Thereafter, at step **404** the removed starch is dried and, where appropriate, packaged.

[0027] A typical starch molecule is illustrated in *Figure 5*. In the source

vegetable, the starch occurs as microscopic granules in the roots and tubers etc. Heating starch with water causes the granules to swell and produce a colloidal suspension from which amylose and amylopectin are derived. The amylose structure is illustrated in *Figure 5* and chains of d-glucose units with
5 alpha-glycosidic linkages present in the amylose molecule tend to cause it to assume a helical arrangement, resulting in a compact shape even though its molecular weight is relatively large.

[0028] Procedures **101c** for the production of a binding agent are
10 illustrated in *Figure 6*. The binding agent comprises at least one starch derivative and/or at least one synthetic resin, and high molecular protein. Starch derivatives and synthetic resins are interchangeable with each other, and the substitution of one with another does not alter the binding agent production process.

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[0029] At step **601** lipids are introduced whereafter at step **602** organic solvent, preferably water, is introduced. At step **603**, a catalyst, such as oxalic acid, may be added. Heat is applied at step **604** thereby encouraging polymerisation. Thus, a typical temperature is 70 degrees
20 Celsius and a typical reaction duration is 90 to 120 minutes. The binding agent, in aqueous form, is thereafter removed at step **605**. During production step **101c**, a solidifying agent may be added depending upon the product intended to be formed from the precursor material.

[0030] Example A: Binding agent composition per metric tonne.

	Methanal	480 kg
	Urea	360kg
5	Gelatine (or agar)	10kg
	Polyvinyl alcohol	10kg
	Melamine	40kg
	Hexamethylenetetramine	20kg
	Triethanolamine (or sorbitol)	640ml
10	Water: ten (10) times by weight of gelatine added to gelatine and polyvinyl alcohol.	

[0031] Example B: Binding agent composition per metric tonne.

As Example A with the Urea, Gelatine (or agar) and Melamine components

15 replaced by Benzene. This composition is not suitable for non-catering products.

[0032] Example C: Binding agent composition per metric tonne.

	Dialdehyde starch	980kg
20	Gelatine or agar	20kg
	Triethanolamine (or sorbitol)	640ml

Water: ten (10) times by weight of gelatine added.

[0033] A typical example of a lipid molecule is illustrated in *Figure 7*. Lipids include a large variety of structural types and the example shown in *Figure 7* is a triacylglycerol. These are typically the oils of plants and the fats of animal origin derived from sources such as peanut oil, soy bean oil and corn oil. The triacylglycerols are usually mixed, such that the acyl groups are different.

[0034] Procedures **102** for the processing of the precursor material are illustrated in *Figure 8*. At step **801** the recovered vegetable material, that has been cleaned and ground as illustrated in *Figure 2*, is introduced. At step **802** this is combined with the starch produced in accordance with the procedures shown in *Figure 4*.

[0035] At step **803** the binding agent, produced in accordance with the procedures shown in *Figure 6*, is added. The mixture is then preferably agitated and dried for between 20 and 60 minutes, preferably in an industrial drying machine. Preferably, the temperature of drying ranges from 60 to 80 degrees Celsius; preferably 70 degrees Celsius. A typical water reduction is 5-10% of overall mass.

[0036] At step **805** the dried first mixture is milled to produce precursor material. The precursor material then takes the form of particles, the size of

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which may vary depending upon the intended application of the precursor material. Thus, for relatively low value products, the particle size is relatively coarse. High value products, possibly ornamental products, would be produced with a finer grain precursor material.

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[0037] In many situations it may be preferable to modify colour characteristics of the precursor material, and hence the intended product, during procedure 102. The precursor material may be coloured by the use of organic or inorganic colouring agent to remove and/or add colour. The use of a particular colouring agent, however, may restrict the degree of application of the precursor material. For example, catering products may be coloured using food or edible colouring only. The precursor material may be bleached, however, to remove colour an inorganic dye such as Titanium dioxide (TiO_2), may be added.

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[0038] As previously stated, at step 103, the precursor material is stored; preferably in a dry environment. A typical shelf life is 7 days when stored in an unsealed environment and 150 days when stored in a sealed environment.

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[0039] Procedure 104 for the production of the mechanical objects is detailed in *Figure 9*. Procedure 104 produces no waste by-product or effluent. At step 901 the press is opened and at step 902 precursor material is introduced into the press. Preferably, a hydraulic machine press is utilised

allowing pressure, temperature and duration to be controlled. Pressing pressure is typically 20 to 25 kiloPascals and it is preferable for at least two pressing operations to be performed. The pressing duration is dependent upon the wetness of the precursor material and a typical first press duration is in the
5 range of 1 to 6 seconds, represented by step **903** in *Figure 9*. After the first pressing operation at step **903**, a breathing operation is performed at step **904**. Thus, the press is released and the product is allowed to breathe for typically 1 to 2 seconds. The breathing operation (blowoff) may be effected by separating the mould into two parts. Thereafter, as shown at step **905**, a second pressing
10 operation is performed for a duration of typically 15 to 90 seconds.

[0040] The mould in which the product is formed is preferably heated to assist the binding process and thus, a typical mould temperature is in the range of 125 to 165 degrees Celsius. The mould may be heated via an
15 electrically heated upper plate and an electrically heated lower plate. Preferably, the upper and lower plates are heated to different temperatures, which facilitates the detachment of the product from the mould and prevents bubbling of the material present in the moulded product. Preferably the lower plate is heated to a higher temperature with the upper plate being heated to a
20 lower temperature thus, a typical temperature for the lower plate is in the range 125 to 155 degrees Celsius and a typical temperature for the upper plate or the mould is in the range 145 to 165 degrees Celsius.

[0041] After the second press at step **905**, the product is removed from the mould at **906**. Thereafter the removed product is allowed to cool naturally, and during this period may be stacked. A question may be asked at step **907** as to whether another object is to be moulded and, when answered in the affirmative, further precursor material may be introduced into the mould at step **902**.

[0042] The product mould, which for example may be fabricated from steel, may be configured to produce a product having intaglio or relief surface ornamentation. Once the product has been removed from the mould, any hand or machine finishing required may be performed. For example, milling of rough edges may be performed, surface decoration may be added and a non-absorbent coating may be applied. Washing of a mechanical object is not necessary, however, whether this is a requirement depends on the application of the product.

[0043] The following Examples D, E, F, G illustrate different precursor material compositions and production processes, and different processes to produce the same mechanical object from precursor material using a two part heated mould.

[0044] Example D

Precursor material composition by weight:

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Binding agent (Example A)	1
Corn flour	0.3
Husk	1.7
Lipid group (zinc stearate)	0.015

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Zinc stearate may be replaced by the following compounds in the equivalent molar quantities:

Calcium stearate

Magnesium stearate

10 Barium stearate

Precursor material production:

The precursor material ingredients are introduced into a mixer. An exothermic reaction occurs at room temperature and pressure with minimum agitation. Reaction duration is 45 minutes. The mixer is opened to release water vapour.

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Although drying of the precursor material is not essential, the precursor material is dried at 75 degrees Celsius for 20 minutes.

20 Mechanical object production:

(Number of blowoffs and blowoff duration dependent on humidity of precursor material)

First pressing duration 5s

		14	
	Blowoff pressing duration	5s	
	Number of blowoff pressings	3	
	Breathing distance	18mm	
	Final pressing duration	18s	
5	Pressure	25kPa/unit	
	Mould temperature	Upper plate	125-135 degrees Celsius
		Lower plate	135-155 degrees Celsius

[0045] Example E

10 Precursor material composition by weight:

	Binding agent (Example A)	1
	Corn flour	0.5
	Husk	1
	Lipid group (zinc stearate)	0.015
15	Titanium dioxide (TiO ₂)	0.05
	Amino solidifying agent	0.003

Amino solidifying agent may be replaced by oxalic acid in the equivalent molar quantity.

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Alternative Precursor material composition by weight:

	Binding agent (Example A)	1
	Corn flour	0.5

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Husk	1
Lipid group	0.015
Organic dye	subject to required colour
Solidifying agent	0.003

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Precursor material production:

The precursor material ingredients are introduced into a mixer. An exothermic reaction proceeds at room temperature and pressure with minimum agitation, producing water vapour. Reaction duration is 60 minutes. The mixer is opened to release water vapour.

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The precursor material is dried at 75 degrees Celsius for 30 minutes.

Mechanical object production:

(Number of blowoffs and blowoff duration dependent on humidity of precursor material)

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First pressing duration	3s
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Blowoff pressing duration	3s
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Number of blowoff pressings	3
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Breathing distance	12-18mm
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Final pressing duration	20s
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Pressure	25kPa/unit
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Mould temperature	Upper plate 145 degrees Celsius
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	Lower plate 155-165 degrees Celsius
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[0046] Example F

Precursor material composition by weight:

	Binding agent (Example A)	1
5	Corn flour	0.5
	Husk	0.9
	Lipid group (zinc stearate)	0.015
	Titanium dioxide (TiO ₂)	0.06
	Amino solidifying agent	0.005
10	Oxalic acid	0.0025

Precursor material production:

The husk is ground into particles having an area of 60 square millimetres.

The precursor material ingredients are introduced into a mixer and mixed
 15 until the temperature inside the mixer achieves 45 degrees Celsius,
 whereafter mixing continues for a further 30 minutes. The precursor
 material is dried at 75 degrees Celsius for 45 to 60 minutes. The precursor
 material is then ground into powder form.

20 Mechanical object production:

(Number of blowoffs and blowoff duration dependent on humidity of
 precursor material)

First pressing duration 3s

		17	
	Blowoff pressing duration	3s	
	Number of blowoff pressings	2-3	
	Breathing distance	10-12mm	
	Final pressing duration	30s	
5	Pressure	25kPa/unit	
	Mould temperature	Upper plate 145 degrees Celsius	
		Lower plate 155-165 degrees Celsius	

[0047] Example G

10 Precursor material composition by weight:

	Binding agent (Example A)	1
	Corn flour	0.5
	Husk	0.8
	Lipid group (zinc stearate)	0.015
15	Titanium dioxide (TiO ₂)	0.068
	Amino solidifying agent	0.005
	Oxalic acid	0.003

20 Titanium dioxide may be replaced by Ultramarine in the equivalent molar quantity.

Precursor material production:

The husk is bleached and ground into particles having an area of 60 square

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millimetres. The precursor material ingredients are introduced into a mixer and mixed at 45 degrees Celsius for at least 60 minutes. The precursor material is then dried at 75 degrees Celsius for approximately 60 minutes. The precursor material is then ground into powder form.

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Mechanical object production:

(Number of blowoffs and blowoff duration dependent on humidity of precursor material)

	First pressing duration	3s
10	Blowoff pressing duration	3s
	Number of blowoff pressings	2
	Breathing distance	10mm
	Final pressing duration	35s
	Pressure	25kPa/unit
15	Mould temperature	Upper plate 145 degrees Celsius
		Lower plate 155 degrees Celsius

[0048] The material produced by the process shown in *Figure 9* is suitable for producing many mechanical objects for use in everyday life. Thus, the process may be used to produce trays for use in domestic environments, fast food environments and medical environments for example. The material is relatively inexpensive to produce and, given its organic origin, will easily biodegrade. Thus, in a fast food environment for example the material has

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significant advantages over non- biodegradable plastics. Furthermore, given the relatively inexpensive nature of the material, many items that presently tend to be reused could themselves be made for one off use, such as the tray shown in *Figure 10*.

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[0049] Many dishes and bowls may be produced by the material, such as the bowl shown in *Figure 11*, for use in a medical environment. Again, a significant advantage of the material is that its relatively low cost allows many items to be produced for one off use. Furthermore, the nature of the material is such that it is relatively easy to dispose of after the single use has been made. In addition, the moulded product may be decontaminated, for example by a UV irradiation, gamma ray sterilisation or ozone sterilisation process.

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[0050] The material is suitable for the production of beverage containers, as illustrated in *Figure 12*. The material has the robustness of a solid plastic or ceramic item but its relatively low cost allows it to be used in applications where the material is discarded.

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[0051] Products that may be formed from precursor material include: disposable food boxes, bowls, cups, plates, trays, cutlery, chopsticks, medical containers and appliances, building materials such as board and bricks; ash trays, candle holders, flower pots, golf balls, computer housings, toys, photo frames, dividers for containers and general packaging.

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[0052] Products formed from precursor material are biodegradable in several natural environments including in water and in soil. The absorption of water assists in polymer breakdown. When disposed in soil, the precursor material degrades to organic fertiliser(s).

[0053] The degradation rate of a mechanical object formed from the same composition of precursor material can be varied by varying the production process as illustrated in Examples H, J, K.

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[0054] Example H

Drying of precursor material	None
Pressing pressure	25kPa
Number of presses	5
Pressing duration	1s, 1s, 1s, 1s, 18s
Mould temperature	Upper plate 125 degrees Celsius
	Lower plate 145 degrees Celsius
Degradation	Starts to degrade within approximately one month of disposal in natural conditions, complete degradation in approximately 6 months.

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[0055] Example J

Drying of precursor material	75 degrees Celsius until moderately dry
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Pressing pressure	25kPa	
Number of presses	4	
Pressing duration	2s, 2s, 2s, 30s	
Mould temperature	Upper plate 125 degrees Celsius	
5	Lower plate 145 degrees Celsius	
Degradation	Starts to degrade within approximately 7 days of disposal in water and soil, complete degradation in approximately 6 months.	
	Starts to degrade within 3-5 months of disposal in natural conditions, complete degradation in approximately 6 months.	

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[0056] Example K

	Drying of precursor material	75 degrees Celsius until drier than Example J
	Pressing pressure	25kPa
15	Number of presses	4
	Pressing duration	2s, 2s, 2s, 25s
	Mould temperature	Upper plate 145 degrees Celsius
		Lower plate 155-165 degrees Celsius
	Degradation	Starts to degrade within 10 days of disposal in water and soil, complete degradation in approximately 6 months.
20		Starts to degrade within approximately 2 months of disposal in natural conditions, complete degradation in approximately 6 months.

[0057] The present invention provides a biodegradable precursor material, from which biodegradable mechanical objects may be formed, displaying one or more of the following properties:

- 5 • Denser than water.
- Variable durability, stability, robustness and flexibility dependent on precursor material composition and manufacture process.
- Variable gloss finish dependent on precursor material composition and manufacture process.
- 10 • Water, oil, ice and other liquids impermeable.
- Odourless.
- Does not contaminate contents of mechanical objects formed from precursor material.
- Temperature resilient between -100°C and $+200^{\circ}\text{C}$. Can be placed in
15 conventional oven at 200 degrees Celsius for typically 120 minutes without distortion of shape. Microwavable for typically 20-120s without distortion of shape.
- Non-flammable to naked flames at room temperature and pressure.
- Full disintegration by incineration.